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Quantum squeezed state analysis of spontaneous ultra weak light photon emission of practitioners of meditation and control subjects

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Research on human ultra-weak photon emission (UPE) has suggested a typical human emission anatomic percentage distribution pattern. It was demonstrated that emission intensities are lower in long-term practitioners of meditation as compared to control subjects. The percent contribution of emission from different anatomic locations was not significantly different for meditation practitioners and control subjects. Recently, a procedure was developed to analyze the fluctuations in the signals by measuring probabilities of detecting different numbers of photons in a bin and correct these for background noise. The procedure was tested utilizing the signal from three different body locations of a single subject, demonstrating that probabilities have non-classical features and are well described by the signal in a coherent state from the three body sites. The values indicate that the quantum state of photon emitted by the subject could be a coherent state in the subject being investigated. The objective in the present study was to systematically quantify, in subjects with long-term meditation experience and subjects without this experience, the photon count distribution of 12 different locations. Data show a variation in quantum state parameters within each individual subject as well as variation in quantum state parameters between the groups.

Keywords: Biophotonics, Human, Meditation, Oxidative stress, Photo count distribution, Squeezed state, Ultra-weak photon emission

Meditation refers to a family of techniques that share a conscious attempt to not dwell on discursive, ruminating thoughts but rather to focus attention in a non-analytical way[1]. Regular use of meditation has been implicated in impacting the homeostasis of the organism and thereby on the level of ROS mediated processes as demonstrated by documenting lower blood (plasma) peroxide levels[2-4] and lower ultra weak photon emission (UPE) in the visible range of the spectrum[5]. The latter technique is non-invasive and directly monitors photons produced mostly by radical reactions related to oxidative metabolism[6].

For recording reactive oxygen species (ROS) related processes in human, UPE is not widely used because the intensity of this emission in the visible range of the spectrum is on the order of less than ~10^2 photons/cm^2 body surface, and its recording requires extreme technical precautions[7-12]. On the other hand, the technique offers additional interesting information both on topographic and time aspects of photon emission that is not obtained with biochemical techniques.

The topographical studies demonstrated the existence of a generic pattern of anatomic distribution of UPE. Thus, thorax-abdomen region emits the lowest emission; the upper extremities and the head region emit the highest levels[9-11]. On the other hand, variations in total intensity of photon counts over the body were quite extensive between subjects.

Results from earlier studies showed that long-term practitioners of transcendental meditation (TM) have generally lower photon emission intensities, while maintaining the same anatomical pattern of emission compared to control subjects without meditation experience[6]. Data were recently confirmed and extended in a study examining the anatomic pattern of photon emission of 20 experienced TM practitioners compared to 20 subjects who practiced other meditation techniques (OTM) and 20 control subjects without experience in meditation. Emission intensities in the TM group and the OTM group were 27 and 17% lower, respectively, compared to the control group. The anatomic pattern of UPE was very similar for the three groups[12].

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The non-invasive recording technology exploring ultra-weak spontaneously emitted light also allows the recording of counts in small consecutive time intervals facilitating photon count distribution studies and the description of quantum optical properties of the signal. The significance of the analysis of the quantum stochastic nature of the photons is interesting since it reflects the properties of the elementary processes of excitation and photon emission. A biological system is a highly integrated organization from the subcellular to the macroscopic (anatomic) level with complex regulation circuitry through elemental interactions. The excitation process in metabolically complex organisms does not originate from statistically independent events. It has been argued that the radiation field emitted by biochemical processes underlying metabolism fluctuates in intensity as a result of the interplay among elementary biochemical reactions in the physiological state [13]. The intensity fluctuations or quantum state (squeezed state) parameters describing fluctuations carry information on the regulatory processes.

Different procedures for the analysis of photon count distribution of photon signals emitted by quasi-stable living organisms, including human, have suggested that low-level photon signals have non-classical features and are in quantum squeezed states[13-20]. However, the conclusion remained suspect because background signal also has some non-classicality which is usually attributed to filtering of low-level signals by a cut-off voltage used in the counting mechanism. Background noise considerably affects the determination of the properties of low intensity signals, and non-classicality of the background enhances this influence. For estimating parameters of the ultra-weak signals emitted by human anatomic locations, the usual procedure of subtracting background contribution is not reliable.

For analysis of human signal, therefore, a strategy was developed that does not resort to background subtractions. Such strategy is based on the assumption that a living system emits a photon signal in a quantum squeezed state specified by two complex parameters α and ζ or, equivalently, by four real parameters $|\alpha|$, r, θ and Φ. All measurable quantities of the signal, including average intensity and various probabilities of detecting photons can be calculated from its quantum state and expressed in terms of the four real parameters[17, 21]. In a recent study, signals from three representative sites of low, intermediate and high emission intensities from one subject were analyzed utilizing both the classical and the novel correction procedure addressing background noise. As a result, the photon signals appeared to exist in a (quantum) squeezed state with almost similar parameter values at each of the three anatomic locations[20].

With the novel analytic procedure, it seemed worthwhile to continue the characterization of the human photon emission and determine the parameters of an assumed squeezed state. The present study examined systematically the photon count distributions of 12 anatomic locations at the upper frontal torso, head, neck and hands of 60 healthy male subjects. Twenty subjects practiced specifically transcendental meditation as taught by Maharishi Mahesh Yogi (TM group), twenty subjects practised other types of meditation, such as yoga, Zen etc. (OTM group), and twenty subjects having no experience in meditation (control group). The squeezed state of the photon signals are utilized to discriminate between individual coherent states and to evaluate the influence of meditation.

Materials and Methods

Subjects—The study included 20 experienced male Transcendental Meditation practitioners (mean age and standard deviation: 51.3±6.7 y), 20 male experienced practitioners of other types of meditation (mean age and standard deviation: 46.3 ± 10.7) and 20 control subjects without experience using any form of meditation (mean age 43.4±15.5). Each of the subjects in the TM group practiced meditation for at least 10 years. It is a mental technique practiced for 20 min twice a day sitting easily with the eyes closed. The technique is taught by Maharishi Mahesh Yogi and learned from an authorized teacher under the auspices of the Maharishi's Global Administration Through Natural Law, Ltd. Some of the practitioners also practiced the more advanced TM-Sidhi program. Subjects in the group "other meditation techniques" were long-term practitioners in one of the following techniques: Zen, Yoga and other personal variations of mindfulness based relaxation techniques. The subjects included in the analysis were, by self-report, healthy and free of medications.

Recording human emission with the photomultiplier—Recording equipment was the same as used in the Van Wijk *et al*[20]. The photomultiplier (9235 QB, selected type; Electron Tubes Limited, Ruislip, England, previously EMI) has a range of 200-

650 nm and was designed for manipulation in three directions. It was mounted in a sealed housing under vacuum with a 52 mm diameter quartz window maintained at –25°C to reduce the dark current (electronic background noise). Dark current was measured before and after each experiment. During the experimental period, the average background noise was 5.2 ± 0.3 cps (counts per second). A spacer (a ring 7 cm high) at the front of the photomultiplier tube allowed the measurement of a 9 cm diameter anatomic area at a fixed distance. The front ring is vented inside, avoiding the condensation of moisture in the quartz window.

The photomultiplier was hung in a dark room in a manner designed for manipulation in three directions. The walls and ceiling of the dark room were covered with mat black paint. The inner size of the dark room was 2 m × 1.5 m × 2 m with an average temperature of 20°C. The room could be vented; the resulting small fluctuations in room temperature gave negligible change in the dark current of the photon-counting device. A bed was positioned in the dark room. The dark room was juxtaposition to the control room which housed the computer system.

Subjects were commonly recorded between 1100-1400 hrs. Before measurement, subjects were shielded from ambient light for at least one hour [9, 10]. Subjects then walked into the dark room and were positioned on the bed for at least 10 min. The photomultiplier tube was placed above the body, the ring at the front port of the photomultiplier touching a particular anatomic area. The duration of each recording was 120 sec consisting of 2400 time intervals of 50 ms. Maximum duration of the measurement cycle inside the darkroom was 45 min.

The selection of 12 anatomic locations used for recording was based on previous spatial characterization of the human photon emission pattern[11]. The distribution of emission along the longitudinal ventral axis and the left and right hands over both palm and dorsal sides were recorded. Exceptions were made at the mouth and navel areas. Both left and right sides at these locations were measured to provide homogeneous skin assessment.

Data analysis—The statistical analysis of photon count data of each set of 2400 data was performed independently, as per Van Wijk *et.al.*[20], utilizing Statistica 6.1 (StatSoft, Tulsa, OK, version 2004).

The assumed squeezed state of signal |α, *r*, θ and Φ emitted by the examined anatomic sites were determined by the minimization program in MATLAB 7.0.4.361: Service PackII (The MathWorks, Inc, Software, 2005). The measurable quantities of the signal were calculated according to Orszag[21] and Bajpai[17]. They are estimated by the least square minimization of the differences between calculated and observed probabilities. The least square minimization procedure results in a F_{min} value, defined as the sum of the square of difference between observed and calculated probabilities.

The correction for background contribution was accomplished by the procedure described earlier[20], assuming that the background and the signals are independent and uncorrelated. The strategy does not resort to simple background subtractions, but instead utilized a correction for background probabilities.

For statistical analysis of group differences, the data were fitted a so called Split-Plot design with three variance components (variance within a subject, variance between subjects, and variances between groups). The model regresses the parameter under study to the subject (as a random factor) and the location and the group as fixed factors. All respective interactions were included.

Results and Discussion

The anatomic locations for multi-site registration of spontaneous emission are at the frontal torso, head and hands (Fig. 1). All selected locations were full skin areas with homogeneous distribution of photon emission, as suggested CCD images of these areas utilizing a special cryogenic cooled CCD camera and 30 min exposure time, and special software for image analysis[11, 22, 23].

Changes in the photon emission at 12 sites in human subjects due to meditation—Figure 2 depicts

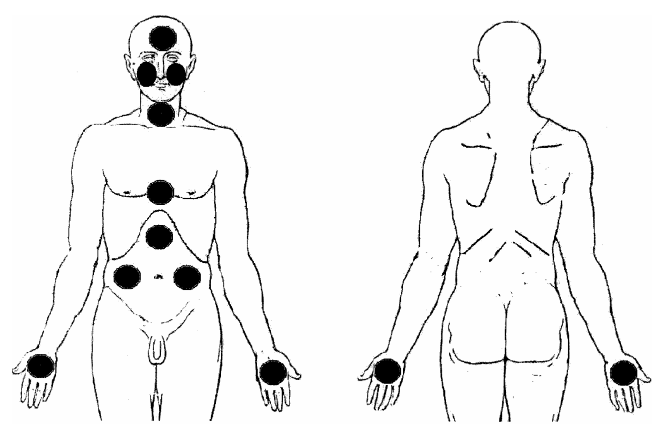

Fig. 1—Anatomic locations for measuring photon emission

group averages of the background signal and strength of photon signals emitted at 12 locations with background signal subtracted. The signals emitted at the lower body parts, at both sides of abdomen and stomach location were of weak strength; the signals the head locations, i.e., throat, cheeks and forehead were of high strength. The signals emitted at the hands also had high strength; the signals at right hand were higher than the signals emitted at the left hand side of similar location. This was a normal pattern found in almost all subjects. The strength of the signal at a location does vary in different subjects but the normal pattern remains intact in every subject[11,13]. The higher strength of photon signals from the right hand is related to the time of measurement during the day. In previous studies it was demonstrated that left-right asymmetry fluctuated diurnally; the right hand higher than the left hand during the day and opposite during the night[24, 25].

Meditation decreases the strength of signals in almost all locations. The amount of decrease was different at different locations and for different subjects. Group intensity values are described in Table 1. The decrease in group averages was around 30 and 20% in TM and OTM group, respectively. The signals emitted at the forehead and both sides of left hand showed higher decrease. The signals emitted by both sides of right hand showed smaller decrease, it was less than 1% in OTM group and around 10% in TM group. The percentage decreases at 12 locations provide 12 scales to measure the success of a subject in a meditation practice. If success in meditation is assumed to represent the state of relaxation and inner calm, then the mean signal strength in a subject should represent a measure of relaxation (or agitation).

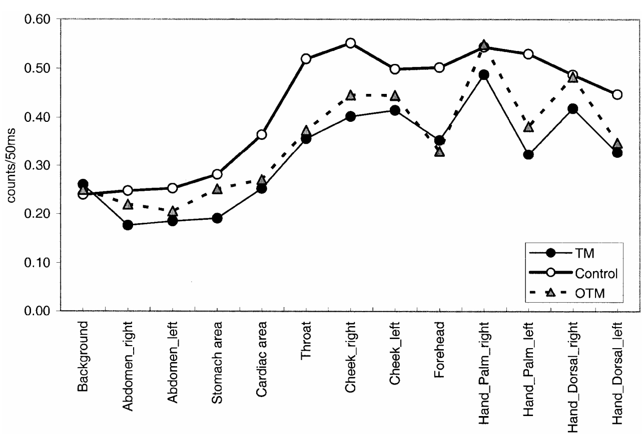

Fig. 2—Group average of signal strength; the group average of background corrected signal strength in TM, control and OTM groups is for signals emitted at 12 sites. The signal strength is in counts/50ms and is obtained after subtracting the mean background from the observed mean of signal. The group average of mean background is also depicted for the three groups.

Figure 3 depicts the group averages of the magnitude of displacement $|\alpha|$ of background and at 12 measured locations. The figure is similar to Figure 2 and conveys essentially the information contained in the previous paragraph. It is the consequence of the proportionality of signal strength at body locations and $|\alpha^2|$. Values of $|\alpha^2|$ for background were much smaller because the background signal was highly squeezed. Group values of $|\alpha^2|$ are described in Table 1. The decrease in average $|\alpha^2|$ was about 9 % in the OTM group and about 14% in the TM group.

Figure 4 depicts r, the magnitude of squeezing, of background signal and of signals at various body locations. The figure shows that the signals of TM group were a little less squeezed. The difference was

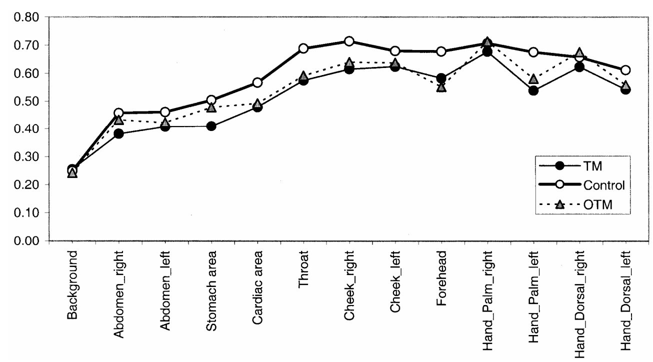

Fig. 3—Group average of $|\alpha|$; the group average of the magnitude of displacement $|\alpha|$ in TM, Control and OTM groups is plotted in for 12 signals and background.

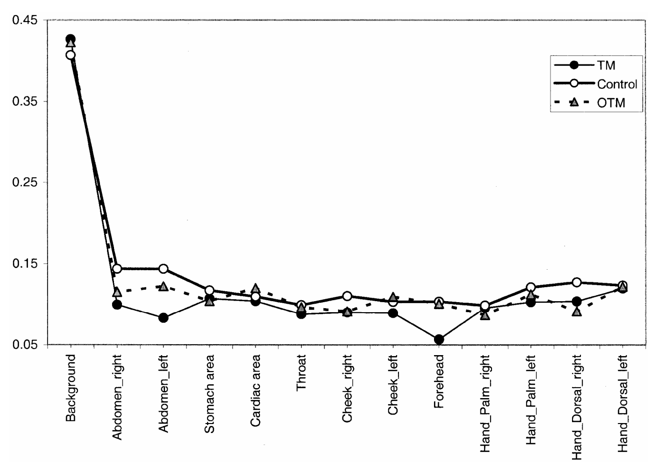

Fig. 4—Group average of r; the group average of the amount of squeezing r in TM, control and OTM groups is plotted for twelve signals and background.

not much and a common value of r at all locations and in the three groups cannot be ruled out. However, the quantitative r-values described in Table 1 show that although the difference was very small, it was decreased less (0. 011) in the OTM group and a little (0.022) more in the TM group.

The phase angle θ is depicted in Fig. 5. There is not much variation between different locations for the different groups. However, when we compare the mean values over the 12 measured locations between the different groups (Table 1), an increase was found in OTM group and even more in TM group. This 'group' pattern is comparable with the intensity and $|\alpha^2|$ values and the reverse for the r values.

Figure 6 shows the φ values. There was little variation between the different groups on the different locations. Also, when group averages were compared the differences were negligible.

Both phase angle θ and φ considerably differ from the corresponding phases of background signal.

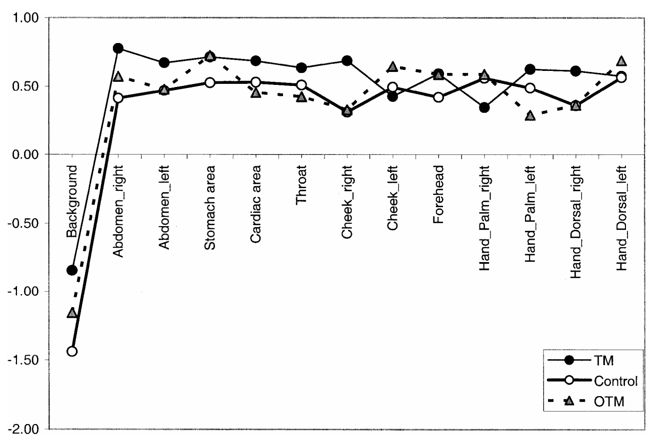

Fig. 5—Group average of θ; The group average of θ in radian in TM, control and OTM groups is plotted for twelve signals and background.

Since the three figures 4, 5, 6 do not rule out the possibility of common squeezed state parameters at various locations in the three groups, we have calculated the mean and standard deviation from the values at 12 locations of the group averages over all 60 subjects. The calculated values were r = 0.106±0.006, θ = 0.53±0.24 radian and φ = 1.16±0.18 radian.

The asymmetries obtained from the values of parameters at similar locations provide another way of investigating the variation of signal with body locations. Our measurements permit the determination of four right-left asymmetries and two palm-dorsal asymmetries. Figure 7 depicts these asymmetries for signal strength. The right-left asymmetries were small in the control subjects and further reduced in the subjects practicing meditation with an exception in the right-left asymmetry of palm side of hand in the TM group that increases slightly. The two palm-dorsal asymmetries were moderate in the control group but large in meditation groups. The behaviour of asymmetries in $|\alpha^2|$ was similar to that of signal

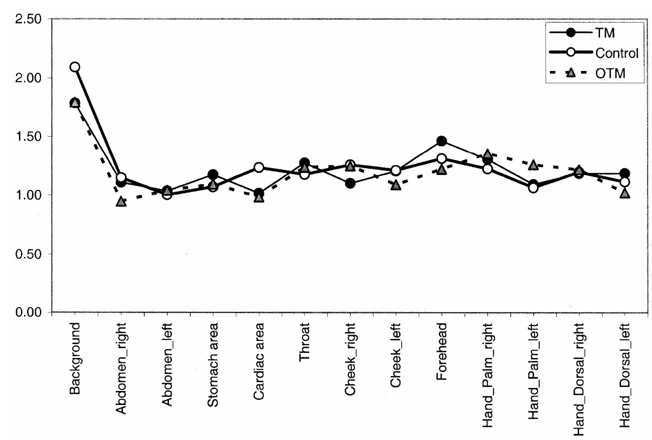

Fig. 6—Group average of φ: and background.

Table 1—Parameters of photon signals averaged over 20 subjects and their 12 measured anatomic locations for the different groups

	CTRL		OTM		TM	
	average(std)	min-max	average(std)	min-max	average(std)	min-max
Signal strength (counts/50ms)	0.435±0.186	0.212-0.967	0.359±0.112	0.218-0.605	0.324±0.078	0.207-0.469
$|\alpha|$(dimensionless)	0.617±0.133	0.419-0.950	0.564±0.082	0.448-0.732	0.538±0.069	0.424-0.681
r (dimensionless)	0.117±0.046	0.029-0.197	0.106±0.050	0.036-0.202	0.095±0.044	0.032-0.181
ϕ (radian)	1.166±0.158	0.848-1.389	1.142±0.164	0.955-1.518	1.177±0.169	0.839-1.520
θ (radian)	0.471±0.168	0.220-0.956	0.512±0.249	0.087-0.923	0.613±0.120	0.3261-.9713
Q	0.298±0.245	-6.52 E-01 -3.63 E-01	0.144±0.479	-1.44 E+00 6.44 E-01	-0.093±0.0866	-3.286-0.742
F_min	$6.63(\times10^{-5})\pm 3.67(\times10^{-5})$	$2.81(x10^{-5}) - 1.54 (\times10^{-4})$	$9.01(\times10^{-5}) \pm 7.99(\times10^{-5})$	$2.47(\times10^{-5}) - 2.47(\times10^{-4})$	$9.11(\times10^{-5}) \pm 9.5\times(x10^{-5})$	$2.15(\times10^{-5}) - 2.64(\times10^{-4})$

strength. The asymmetries in the other three squeezed state parameters were small and do not show any definite pattern.

Another indicator of the nature of a series of measurements is Q value, whose group average is plotted in Fig. 8. The background signals had nearly same values of Q. The values were much higher than the values of Q in signals. The values indicate that the probability distribution of photons in background is highly super Poisson. The probability distributions in the signals differ only slightly from Poisson distribution. A significant feature of Fig. 8 is the negative values of Q at many locations in the TM group. A negative value of Q in a signal implies sub Poisson distribution of probabilities and quantum nature of the signal. Q was negative at few locations in many subjects of the OTM group. Table 1 illustrate that the group averages of Q in the three groups is small and the group averages of Q at different locations of the OTM group (0.144) lie between the corresponding group averages of the Control (0.298) and TM (-0.093) groups.

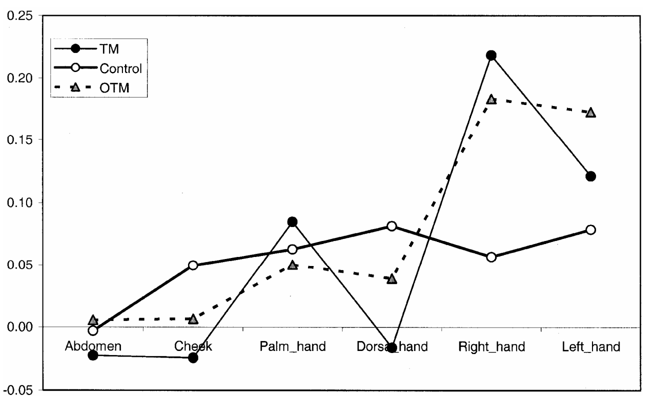

Fig. 7—Group average of asymmetry in signal strength; the group average of six asymmetries is plotted for TM, control and OTM groups.

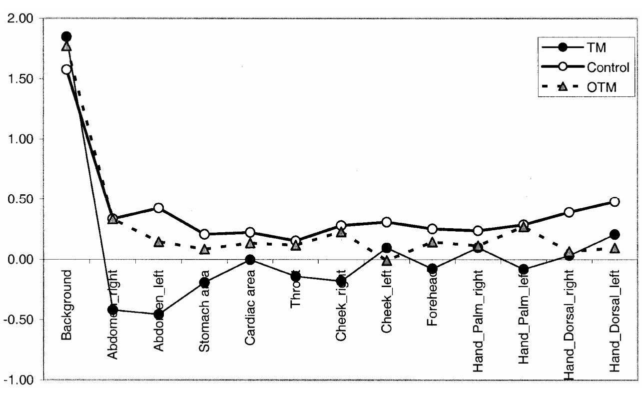

Fig. 8—Group average of Q; the group average of the background corrected Q in TM, control and OTM groups is plotted for twelve signals and background.

The next step was to evaluate the efficacy of parameters of the assumed squeezed state in identifying a subject and in discriminating among different subjects. Results for the different parameters are presented in Table 2. It presents the variances between subjects and within subjects.

Groups were compared by fitting a model with three variance components (variance within a subject, variance between subjects, and variance between groups). The model was a so-called Split-Plot design which regresses the parameter under study to the subject (as a random factor) and the location and the group as fixed factors. All respective interactions are included.

Within these models we can confirm overall group differences for $|\alpha|$ (p=0.0446) but not for φ (p=0.7857), r (p=0.3467), or θ (p=0.0961). There are not hints that there might be an interaction between the group and the location (in other words: we cannot find that the group differences vary from location to location): the respective p-values are: *P*=0.2307 (for $|\alpha|$), *P*=0.5775 (for φ), *P*=0.8170 (for r), and 0.1276 (for θ). But there are differences between the 12 locations for $|\alpha|$ (*P*=0.0001), φ (*P*=0.0003), and r (*P*=0.0358) but not for θ (*P*=0.3050).

Common values of parameters in different signals is an interesting observation that is investigated by calculating the parameters after imposing constraints of having common parameters in signals at all sites and also all subjects of a group. The averages and standard deviations of the parameters calculated with and without constraints are given in Table 3. The parameters in the serial number 1 are averages of squeezed state parameters calculated independently for each signal. The parameters in the serial number 2 are averages of the squeezed state parameters calculated with the constraint that signals at 12 sites have same values of r, θ and φ in a subject. The parameters in the serial number 3 are squeezed state parameters calculated with the constraint that signals at 12 sites in all subjects have same values of r, θ and φ. The table shows that squeezing parameter r is small but differs slightly in three groups. The Meditation

Table 2—Variances between subjects and within subjects

Squeezed state parameter	Variance between subjects	Variance within subjects
$\lvert\alpha\rvert$	0.0097	0.0089
ϕ	0.1612	0.0123
r	0.0019	0.0018
θ	0.0257	0.0256

Table 3—Average and standard deviation of squeezed state parameters r, θ and φ, calculated for signals at 12 sites in 60 subjects. The results are given for TM, Control and OTM groups as well as for all subjects. The table also gives the results calculated with two constraints

S. No.	Constraint	Parameter	TM group	Control group	OTM group	All subjects
1	No constraint	r	0.095±0.005	0.117 ±0.006	0.108±0.006	0.106±0.006
		θ	0.61±0.26	0.48 ± 0.19	0.52±0.27	0.54±0.24
		φ	1.18±0.21	1.17 ± 0.16	1.13±0.17	1.16±0.18
2	Same values at 12 sites in a subject	r	0.064±0.004	0.094 ± 0.004	0.087±0.005	0.082±0.004
		θ	0.51±0.72	0.51 ± 0.09	0.50±0.22	0.51±0.34
		φ	1.37±0.16	1.18 ±0.07	1.15±0.12	1.23±0.12
3	Same values at 12 sites in all subjects	r	0.025	0.084	0.034	0.042
		θ	-0.53	0.66	0.51	0.31
		φ	1.30	1.34	1.83	1.39

group yields the smallest value while the control group yields the highest value in the three sets of results. The same result was depicted in Fig. 4, where average of r was taken at each site over subjects of three groups. Figure 4 and Tables 1 and 3 demonstrate that meditation decreases the amount of squeezing r and the decrease is more in the TM group. The table further shows that the constraint of having common parameter decreases the calculated value of r; higher the number of signals with common parameters, more is the decrease. Perhaps, the signals at 12 sites do not have same value of r. The values probably lie in a small band that differs slightly in different subjects. The other two parameters, not so well determined, also differ in the three groups. The differences were, however, not large and same values in the three groups cannot be ruled out. The value of θ was negative in the TM group in serial number 3, which is not serious for sign affects only the probabilities of detecting large number of photons, which were small. The fitting with positive sign will not be very different.

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